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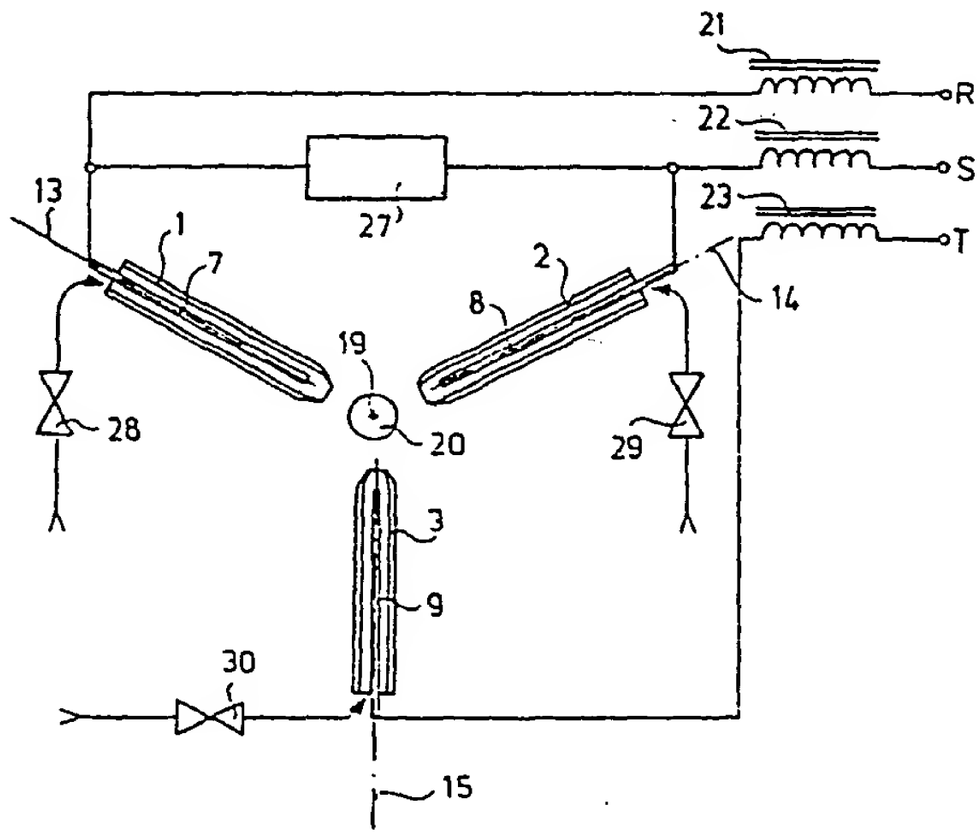
(54) Title: APPARATUS FOR MACHINING BY THE MEANS OF A PLASMA BEAM A WORKPIECE MADE OF A MATERIAL OF HIGH SOFTENING OR MELTING POINT, ESPECIALLY QUARTZ, GLASS OR A METAL



(57) Abstract

In an apparatus for machining by the means of a plasma beam a workpiece made of a material of high softening or melting point, especially quartz, glass or a metal, comprising at least three electrodes (7, 8, 9) connected to a current supply of a least three phases (R, S, T) and nozzles (1, 2, 3) transporting by their outlets gas for creating a plasma beam into a field of the electrodes (7, 8, 9), the nozzles (1, 2, 3) receiving in a coaxial arrangement the electrodes (7, 8, 9), the novelty lies in applying the nozzles (1, 2, 3) containing the field creating electrodes (7, 8, 9) in an arrangement characterized by rotational symmetry around a symmetry axis (19) wherein the outlets of the nozzles (1, 2, 3) are placed equidistantly from the symmetry axis (19) of the rotational symmetry, the symmetry axis (19) forming a line within a workpiece (20) to be machined, and the longitudinal axes (13, 14, 15) of the nozzles (1, 2, 3) and electrodes (7, 8, 9) are arranged in an angular range determined with respect to the symmetry axis (19) by maximal inclination $\pm 15^{\circ}$ from a plane perpendicular to the symmetry axis (19).

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APPARATUS FOR MACHINING BY THE MEANS OF A PLASMA BEAM A WORKPIECE MADE OF A MATERIAL OF HIGH SOFTENING OR MELTING FOINT, ESPECIALLY QUARTZ, GLASS CR A METAL

BACKGROUND OF THE INVENTION

The present invention refers to an apparatus for machining by the means of a plasma beam a workpiece made of a material of high softening or melting point, especially quartz, glass or a metal. According to the art the proposed apparatus comprises at least three electrodes connected to a current supply of at least three phases and nozzles transporting by their outlets gas for creating a plasma beam into a field determined by the electrodes, wherein the nozzles receive the electrodes in a coaxial arrangement for generating the plasma beam.

The apparatus proposed by the present invention may be applied advantageously in laboratories and factories requiring softening of quartz and glass type materials and further in technological processes wherein a special heat or other treatment, surface treatment is necessary, e.g. in the case of metals.

DISCUSSION OF THE BACKGROUND ART

In the practice of machining workpieces made of quartz or glass the workpiece undergoes softening by means of an oxygen based flame. The high temperature of machining results in polluting the workpiece by the products of the combustion process generating the flame. According to the general opinion the OH (hydroxyde) content of quartz increases. This can be highly disadvantageous, especially when a technological process with high demands on purity is required. For assuring the low contamination level a technology is known wherein a plasma burner is arranged in

a protective atmosphere consisting e.g. of a rare gas or nitrogen. A very important feature of this prior art solution is the requirement of assuring the high stability of the plasma beam and excluding conditions wherein the working medium of the plasma beam can react with the material to be machined in the temperature of machining. The requirements mentioned can be met in the processes and apparatuses of the prior art in many steps, by applying very sophisticated constructions.

The specification of the German Patent DE-A1 31 36 799 discloses an apparatus supplied by electric current from a three-phase alternating current supply. The electrodes of this apparatus are arranged concentrically in respective nozzles for forwarding protective gas. The three nozzles and electrodes are arranged with outlets lying on the mantle of a cylinder or a cone. This apparatus can work only with metallic workpiece to be machined and the requirement of generating a stable plasma beam results in a maximal possible length of the spacing between the electrodes. This means, the known apparatus is not capable of over-annealing a workpiece or machining non-conductive materials, i.e. non-metallic workpieces.

SUMMARY OF THE INVENTION

The present invention is directed to creating an apparatus for machining, by the means of a plasma beam, a workpiece made of a material of high softening or melting point, especially quartz, glass or a metal, whereby it is possible to avoid the disadvantages characterizing the solution of the background art, i.e. to machine either metallic or non-metallic workpieces by simple means ensuring annealing, surface or volumetric heat treatment. The apparatus according to the present invention should be applicable in different technologic

processes only by selecting an appropriate working medium and/or current supply and be realisable with small dimensions ensuring low energy demand.

The present invention is based no the recognition that the workpieces made of different metallic and non-metallic materials can be machined in a simple way, with high reproductivity and low energy demand if the workpiece is heated up by a plasma burner comprising electrodes connected to a current supply of at least three phase, applying as working medium a protective gas or a rare gas, wherein the electrodes are arranged for generating a stable plasma beam in the absence of the workpiece to be machined, too.

Thus, the present invention refers to an apparatus for machining, by the means of a plasma beam, a workpiece made of a material of high softening or melting point, especially quartz, glass or a metal, comprising at least three electrodes connected to a current supply of at least three phases and nozzles transporting by their outlets gas for creating a plasma beam into a field determined by the electrodes, and the nozzles include the electrodes in a coaxial arrangement. The improvement of the apparatus lies in applying the nozzles containing the electrodes in an arrangement of rotational symmetry around a symmetry axis wherein the outlets of the nozzles are placed equidistantially from the symmetry axis of the rotational symmetry, the symmetry axis forms a line within a workpiece to be machined and the longitudinal axes of the nozzles are arranged in an angular range determined with respect to the symmetry axis by maximal inclination $\pm 15^{o}$ from a plane lying perpendicularly to the symmetry axis. The arrangement of the electrodes and nozzles as required by the invention ensures that the plasma beam shows circular symmetry and high stability in time and space during machining and the features mentioned can be ensured independent on the shape

and material of the workpiece, i.e. a non-metallic element of cylindric symmetry can be machined, too.

If the workpiece to be machined is a small, point-like element it is advantageous to arrange the nozzles in a way that their longitudinal axes cross one another in a common point lying on the symmetry axis.

For machining workpieces of bigger dimensions it is advantageous to arrange the nozzles in a way that their longitudinal axes form tangents of a circle line drawn around a central point lying on the symmetry axis. In this way the ionized gas of the plasma beam embraces the workpiece to be machined ensuring thereby high uniformity and controlability of the process of machining.

The basic and generally applicable embodiment of the apparatus according to the invention comprises three electrodes connected to a respective phase of a three-phase current supply, i.e. each phase is coupled with a separate electrode. For machining workpieces of big dimensions can be, however, advantageous to apply more than three, namely n times three (wherein n is an integer), e.g. six phases connected to respective electrodes. In this case each phase of the more-phase current supply is coupled with a separate electrode; each electrode is, however, supplied from one phase.

The uniform heating and machining of the workpiece can be obtained also by means of a three-phase current supply feeding n times three electrodes (n is an integer), wherein in phase ensures supply to n electrodes, i.e. in the case of a six-electrode system each phase is coupled with two electrodes. In an arrangement of such kind the stability of the plasma discharge process is a bit lower than on applying number of phases equal to the number of the electrodes, the circuit arrangement is more simple. In the advantageous arrangement of more electrodes supplied from one phase the electrodes can be connected in different

manners to the phase. In a six-electrode arrangement it is advantageous to arrange the electrodes connected to the same phase oppositely to one another, with longitudinal axes crossing the symmetry axis.

The over-annealing and heat treatment of long workpieces, especially wires can be simply carried out if the proposed apparatus includes more sets of electrodes arranged in planes determined along the symmetry axis. In this way the power of the apparatus can be improved without increasing the heat load of the separate electrodes. It is also preferred that the workpiece can be heated up in more steps, avoiding thereby the unwanted preheating of its surface, if necessary.

In many technologic processes it is required to protect the workpiece from the outer atmosphere. The invention offers the possibility of arranging the electrodes and the workpiece in a space separated from the ambient atmosphere.

The apparatus realised according to the invention is capable of machining metallic and non-metallic workpieces made e.g. of quartz or glass by generating a plasma beam causing no contamination of the workpiece.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further described in more detail with reference to the attached drawings showing non-limiting examples of the apparatus proposed by the present invention. In the drawings

FIG. 1 is a schematic view of a three-phase three--electrode embodiment of the apparatus proposed by the invention,

FIG. 2 is a schematic view of an apparatus proposed by the invention, comprising more times three electrodes arranged in different planes,

FIG. 3 is a schematic view of a six-phase six-electrode

embodiment of the apparatus proposed by the invention, and

FIG. 4 is a schematic view of a three-phase six-electrode embodiment of the apparatus proposed by the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As it is shown on the example of a three-electrode embodiment the apparatus proposed by the invention (FIG. 1) comprises three nozzles 1, 2, 3 in an arrangement of the rotational symmetry. The nozzles 1, 2, 3 are arranged equidistantially, with an angle distance 120^{o}, they include electrodes 7, 8, 9 having longitudinal axes 13, 14, 15. The arrangement of the rotational symmetry is determined by a symmetry axis 19 which includes the common crossing point of the longitudinal axes 13, 14, 15. The symmetry axis 19 lies within a workpiece 20 made e.g. of quartz represented by a circle line on the FIG. 1. The symmetry axis 19 is represented by a point. The electrodes 7, 8, 9 consist of a tungsten alloy including thorium, their diameter is 1 mm, their tips form a cone. They are connected by means of choking coils 21, 22, 23 to phases R, S, T of a three-phase network applied as a current supply. The nozzles 1, 2, 3 are made in the form tubes consisting of quartz, ceramics or a metal of high melting point equipped with a cooling system. The inner diameter of the nozzles 1, 2, 3 is 4 mm, their inner space are connected by the means of regulating valves 28, 29, 30 to a gas source not shown in the drawings. The gas source comprises for example argon. The shape, power density of the plasma beam generated between the electrodes 7, 8, 9 can be regulated by changing the volume flux of the gas. In extreme cases the plasma beam can be applied for concentric heating on a small surface area or for heating a big surface of the workpiece. The applied supply voltage is 3 x 380 V, 50 Hz,

the phase current 8 to 10 A. The plasma beam can be initiated by high-frequency ignition means connected to the current supply.

The apparatus proposed by the invention may comprise a higher number of electrodes arranged in different places along the symmetry axis 19. The workpiece 20 to be machined, i.e. a tungsten wire is forwarded in the line of the symmetry axis 19 and it passes three systems consisting of three nozzles 1, 2, 3 which include respective electrodes 7, 8, 9. The workpiece 20 undergoes over-annealing along the símmetry axis 19 during its translation realised with velocity about 2.10^{-2} m/s in the space determined by the nozzles 1, 2, 3. The apparatus is placed in a housing 34 arranged for receiving the workpiece 20 at one inlet plane and for forwarding it at the outlet plane, the inlet and outlet planes intersecting with the symmetry axis 19. The nozzles 1, 2, 3 introduce argon gas to the inner, working space of the housing 34 which is separated thereby from the ambient atmosphere.

The embodiments of the apparatus according to the invention with six electrodes is shown in FIG. 3 when supplying from a six-phase arrangement and in FIG. 4 when supplying from a three-phase arrangement.

In FIG. 3 a possible six-nozzle arrangement is demonstrated, wherein nozzles 1, 2, 3, 4, 5, 6 are arranged together with electrodes 7, 8, 9, 10, 11, 12 in a rotated position. wherein the nozzles 1, 2, 3, 4, 5, 6 have longitudinal axes 13, 14, 15, 16, 17, 18 forming tangents of a circle enclosing the workpiece 20, wherein the central point of the circle lie on the symmetry axis 19. This solution can be especially advantageous when the workpiece 20 is of great dimensions, because the ionized gas entering the space between the electrodes 7, 8, 9, 10, 11, 12 from the outlets of regulating valves 28, 29, 30, 31, 32, 33 surrounds the workpiece 20 to be machined in a more pre-

cise manner than in the case of arranging the nozzles 1, 2, 3, 4, 5, 6 with longitudinal axes 13, 14, 15, 16, 17, 18 crossing the symmetry axis 19.

In the arrangement shown in FIG. 3 the six-phase electric supply is ensured by the means of separating transformers 35, 36, 37, wherein the electrodes 7, 8, 9, 10, 11, 12 are connected to phases R, S, T, U, V, Z through choking coils 21, 22, 23, 24, 25, 26. The separating transformers 35, 36, 37 are connected to the phases R, S, T of the three-phase supply network.

In the arrangement shown in FIG. 4 the electrodes 7, 8, 9, 10, 11, 12 are connected to the three phases R, S, T of the supply network by the means of choking coils 21, 22, 23, 24, 25, 26. In this arrangement it is especially advantageous to connect with the same phase, e.g. signed by R two electrodes signed by 7 and 10 and arranged oppositely, i.e. along the same diameter determining the arrangement of the electrodes 7, 8, 9, 10, 11, 12.

The apparatus according the invention operates in the manner of the known plasma apparatuses, i.e. the electrodes generates a plasma beam for machining the workpiece 20, wherein the plasma beam is realised independently on the material of the workpiece.

WHAT WE CLAIM IS:

1. An apparatus for machining by the means of a plasma beam a workpiece made of a material of high softening or melting point, especially quartz, glass or a metal, comprising at least three electrodes (7, 8, 9) connected to a current supply of at least three phases (R, S, T) and nozzles (1, 2, 3) transporting by their outlets gas for creating a plasma beam into a field of the electrodes (7, 8, 9), the nozzles (1, 2, 3) receiving in a coaxial arrangement the electrodes (7, 8, 9),

characterized in

applying the nozzles (1, 2, 3, 4, 5, 6) containing the electrodes (7, 8, 9, 10, 11, 12) in an arrangement of rotational symmetry around a symmetry axis (19) wherein the outlets of the nozzles (1, 2, 3, 4, 5, 6) are placed equidistantially from the symmetry axis (19) of the rotational symmetry, the symmetry axis (19) forming a line within a workpiece (20) to be machined, and the longitudinal axes (13, 14, 15, 16, 17, 18) of the nozzles (1, 2, 3, 4, 5, 6) are arranged in an angular range determined with respect to the symmetry axis (19) by maximal inclination $\pm 15^{o}$ from a plane perpendicular to the symmetry axis (19).

2. The apparatus as set forth in claim 1,

characterized in

the arrangement of rotational symmetry including the longitudinal axes (13, 14, 15, 16, 17, 18) of the nozzles (1, 2, 3, 4, 5, 6) crossing one another in a common point lying on the symmetry axis (19).

3. The apparatus as set forth in claim 1,

characterized in

the arrangement of rotational symmetry including the longitudinal axes (13, 14, 15, 16, 17, 18) of the nozzles (1, 2, 3, 4, 5, 6) forming tangents of a circle having central point on the symmetry axis (19).

4. The apparatus as set forth in any of claims 1 to 3,

characterized in

comprising three times n electrodes (7, 8, 9, 10, 11, 12)

wherein n is an integer and in connecting each phase (R, S, T, U, V, Z) of the more phase current supply to a separate electrode (7, 8, 9, 10, 11, 12).

5. The apparatus as set forth in any of claims 1 to 3, characterized in comprising a three-phase (R, S, T) current supply and three times n electrodes (7, 8, 9, 10, 11, 12) wherein n is an integer and each phase (R, S, T) is connected to n electrodes (7, 8, 9, 10, 11, 12).

6. The apparatus as set forth in claim 5, characterized in comprising six electrodes (7, 8, 9, 10, 11, 12) divided into three groups connected respectively to the separate phases (R, S, T) of the current supply, the groups consisting of two electrodes (7, 8, 9, 10, 11, 12) arranged in a spaced opposition to one another with respect to the symmetry axis (19).

7. The apparatus as set forth in any of claims 1 to 6, characterized in comprising at least two sets of nozzles (1, 2, 3, 4, 5, 6) and electrodes (7, 8, 9, 10, 11, 12), each set being arranged along the symmetry axis (19).

8. The apparatus as set forth in any of claims 1 to 7, characterized in arranging the electrodes (7, 8, 9, 10, 11, 12) and the workpiece (20) in a space separated from the ambient atmosphere.

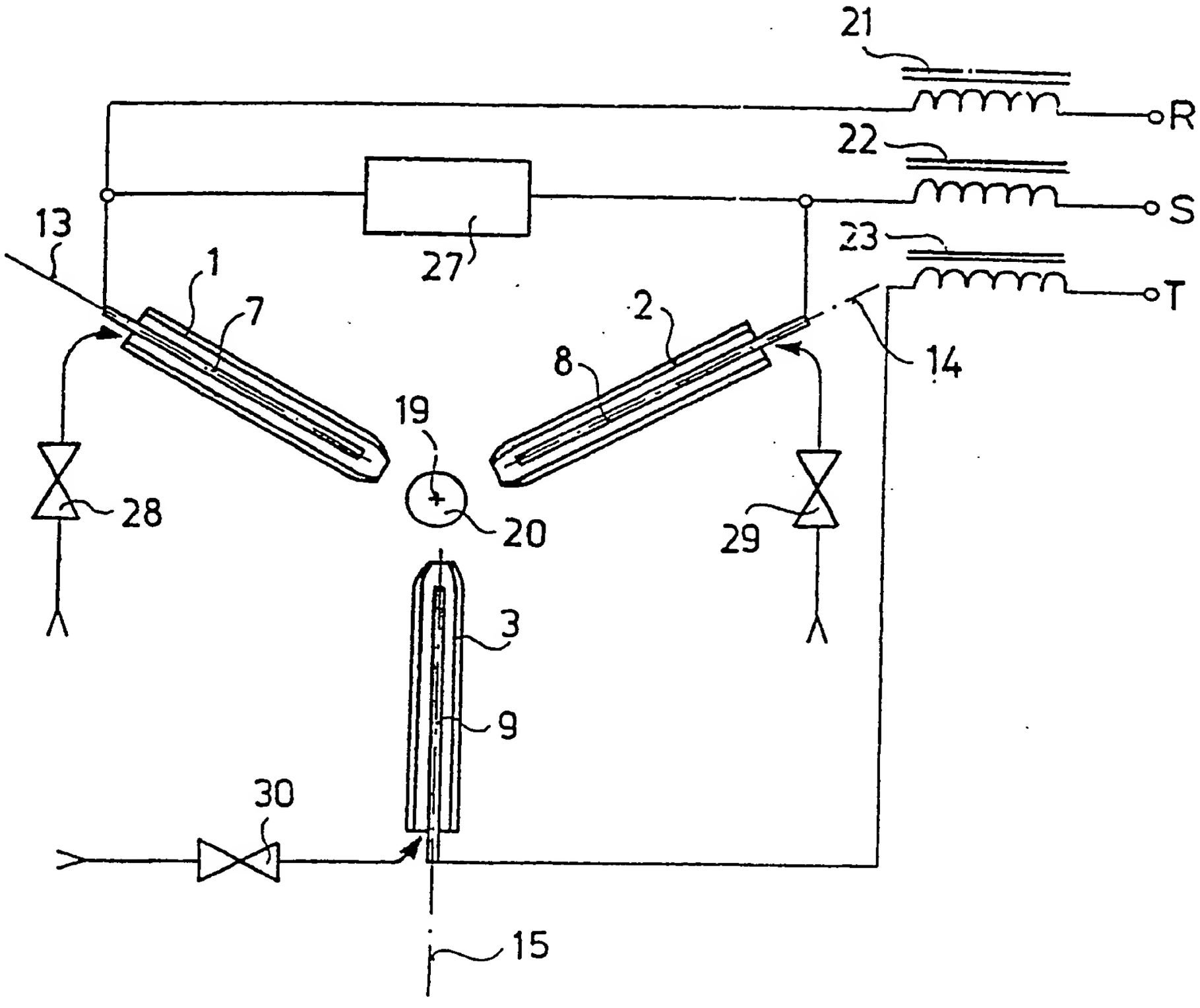

Fig.1

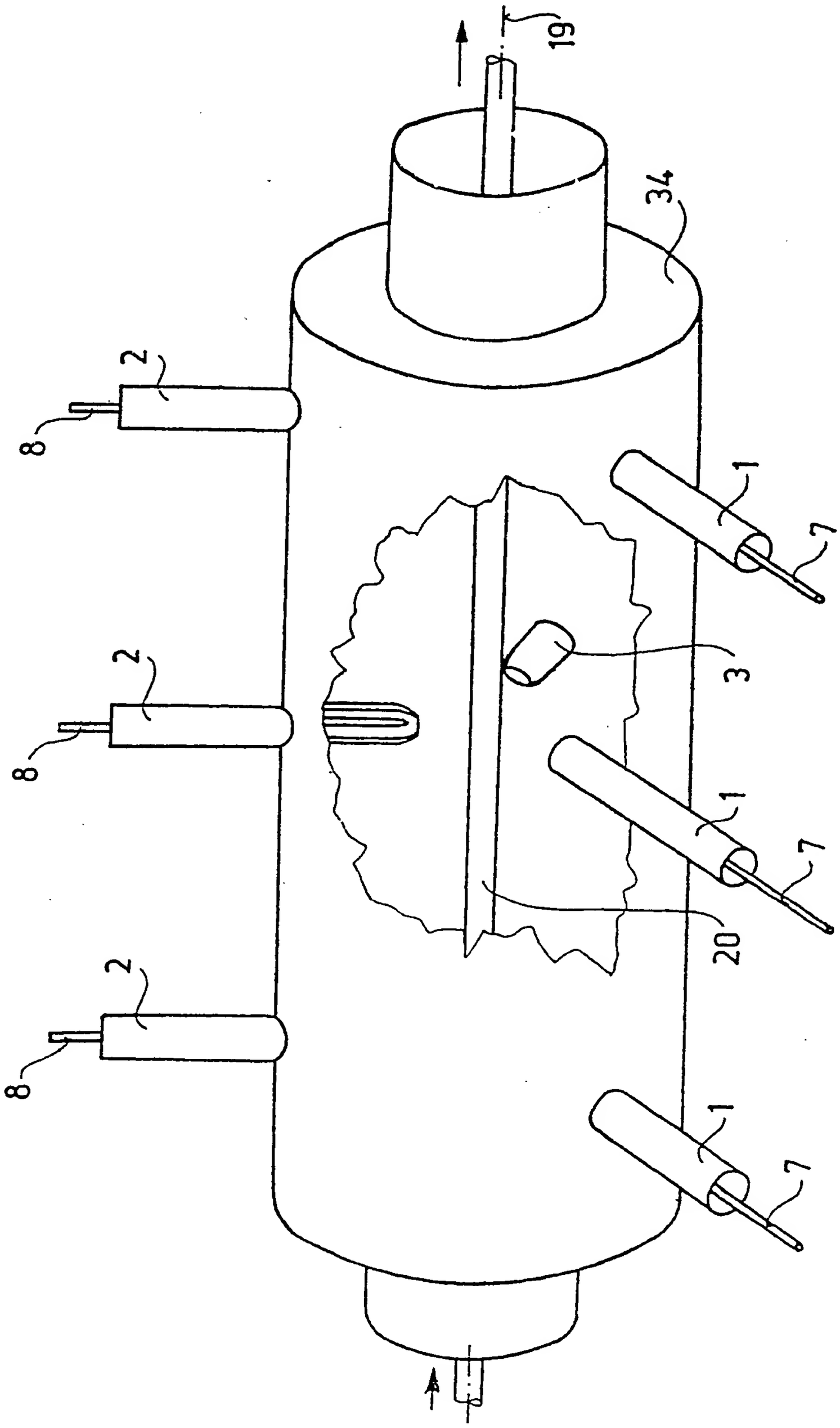

Fig. 2

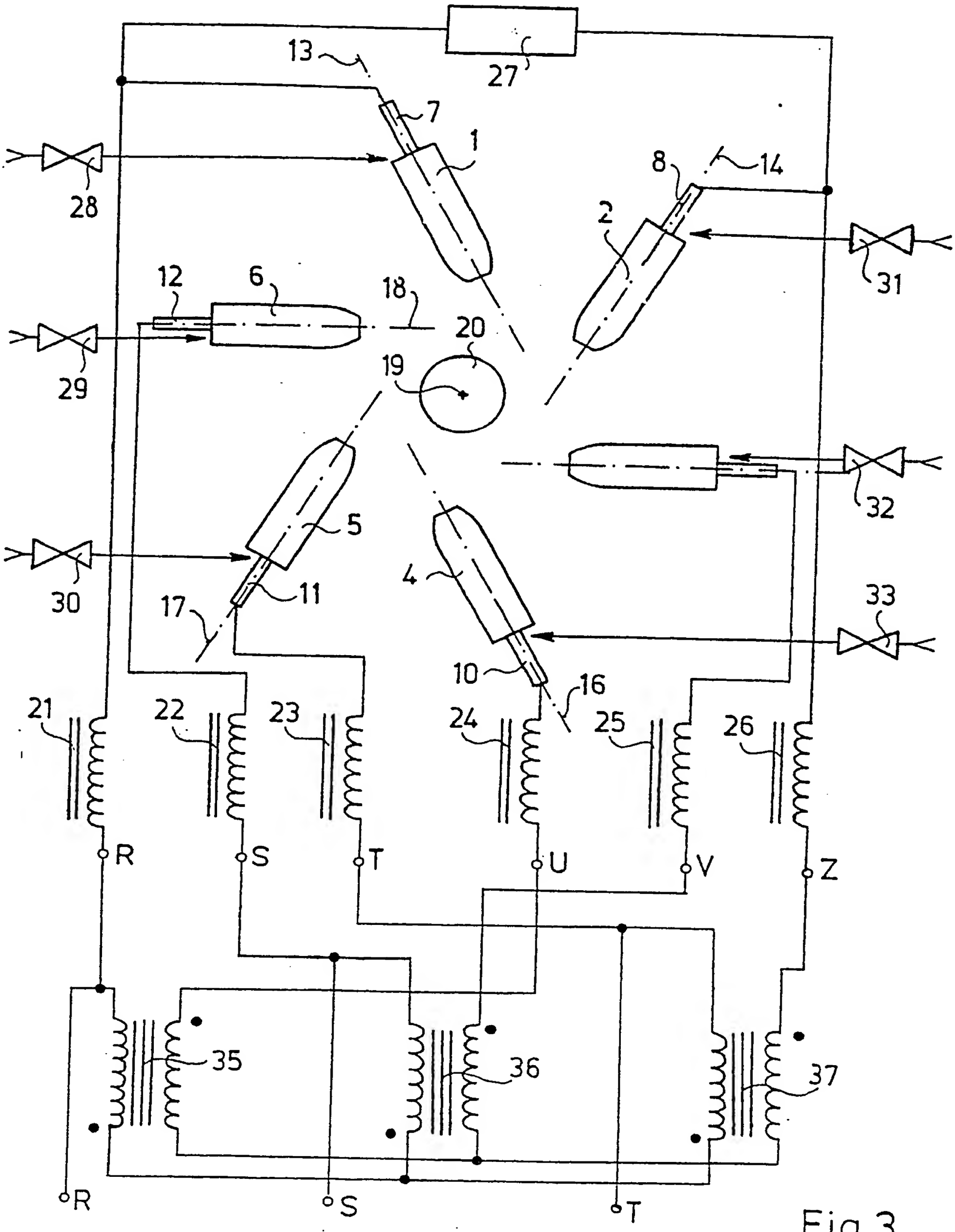
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Fig.3

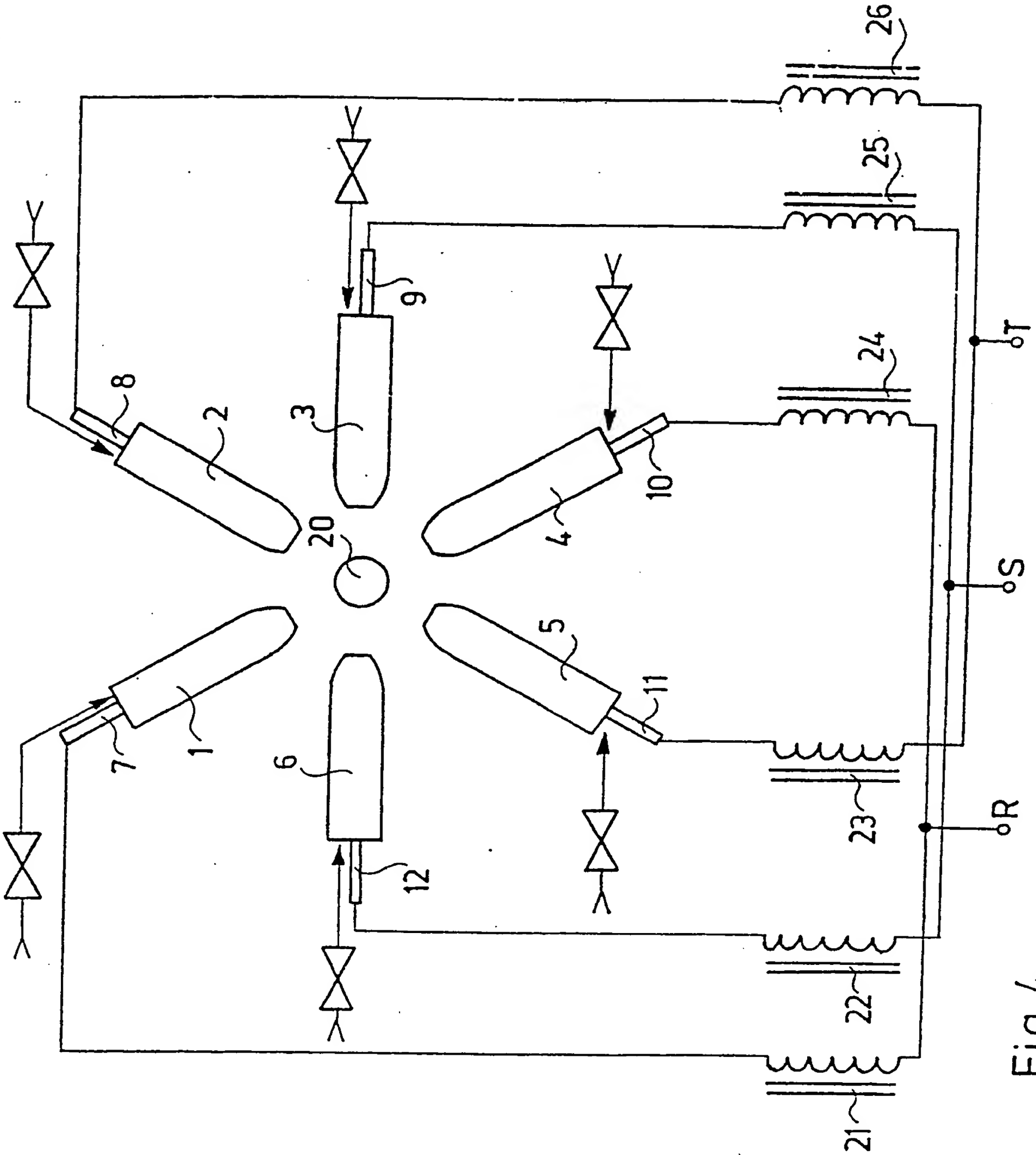

Fig.4

INTERNATIONAL SEARCH REPORT

International Application No PCT/HU 89/00040

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[5]: B 23 K 28/00

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
Int.Cl.[5]	B 23 K 28/00, H 05 H 1/42-1/46

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X A	US, A, 3 541 297 (J.A.F.SUNNEN) 17 November 1970 (17.11.70), see fig. 1,10.	(1,2) (4-8)
X A	US, A, 3 798 408 (FOEX et al.) 19 March 1974 (19.03.74), see fig. 8.	(1,2) (4-8)
A	US, A, 3 770 935 (TATENO et al.) 06 November 1973 (06.11.73), see fig. 1.	(1,2,4-8)
A	US, A, 2 972 696 (A.R.KANTROWITZ) 21 February 1961 (21.02.61), see fig. 1.	(1,2,4-8)
A	DE, B, 1 758 483 (INSTITUT ELEKTROSWARKI) 11 February 1971 (11.02.71), see fig. 2.	(1,3)
A	DE, A, 2 014 592 (LA SOUDURE) 08 October 1970 (08.10.70), see fig. 12.	(1)

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
14 December 1989 (14.12.89)	20 December 1989 (20.12.89)
International Searching Authority	**Signature of Authorized Officer**
AUSTRIAN PATENT OFFICE	

Anhang zum internationalen Recherchenbericht über die internationale Patentanmeldung Nr.

In diesem Anhang sind die Mitglieder der Patentfamilien der im obengenannten internationalen Recherchenbericht angeführten Patentdokumente angegeben. Diese Angaben dienen nur zur Unterrichtung und erfolgen ohne Gewähr.

Annex to the International Search Report on International Patent Application No. PCT/HU 89/00040

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned International search report. The Austrian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Annexe au rapport de recherche internationale relatif à la demande de brevet international n°.

La présente annexe indique les membres de la famille de brevets relatifs aux documents de brevets cités dans le rapport de recherche internationale visé ci-dessus. Les renseignements fournis sont donnés à titre indicatif et n'engagent pas la responsabilité de l'Office autrichien des brevets.

Im Recherchenbericht angeführtes Patentdokument Patent document cited in search report Document de brevet cité dans le rapport de recherche	Datum der Veröffentlichung Publication date Date de publication	Mitglied(er) der Patentfamilie Patent family member(s) Membre(s) de la famille de brevets	Datum der Veröffentlichung Publication date Date de publication
US-A - 3541297	17-11-70	DE-A - 1950132	09-04-70
		FR-AS- 2020022	10-07-70
		NO-B - 124232	20-03-72
US-A - 3798402	19-03-74	US-A - 3714390	30-01-73
		DE-A - 2162024	07-09-72
		DE-B2- 2162024	10-08-78
		DE-C3- 2162024	04-10-79
		FR-A6- 2119179	04-08-72
		GB-A - 1380719	15-01-75
		DE-A - 1965576	27-09-70
		DE-B2- 1965576	25-11-76
		DE-C3- 1965576	28-07-77
		FR-A - 1600278	20-07-70
		GB-A - 1298680	06-12-72
US-A - 3770935	06-11-73	CH-A - 543711	14-12-73
		DE-U - 7148539	27-04-72
		DE-A - 2164270	13-07-72
		DE-B2- 2164270	09-05-74
		DE-C3- 2164270	05-12-74
		FR-A5- 2119768	04-08-72
		GB-A - 1346790	13-02-74
		JP-B4-49032691	02-09-74
		JP-A2-48037345	01-06-73
		JP-B4-52010809	26-03-77
US-A - 2972696		None	

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DE-B - 1758483	11-02-71	DE-A - 1758483	11-02-71
DE-A - 2014592	08-10-70	FR-A5- 2039566	15-01-71
		JP-B4-5001107	26-04-75
		US-A - 3660630	02-05-72

For more details about this annex: see Official Journal of the European Patent Office, No. 12/82.